shearing was nearly completed, with the clip excellent. The range was fine and stock thriving.—*R. J. Hyatt.*

Virginia.—With the exception of a cold period from the 17th to 19th, when killing frosts and ice occurred, and a local droughty condition during the month in portions of the great valley division, the general weather prevailing through the month was favorable for crop progress. Winter wheat and oats advanced steadily, and field work incident to the season was vigorously carried on. Some corn was planted and tobacco plants were abundant and thrifty. Gardens, truck crops, and fruit were considerably injured by frost.—*Edward A. Evans.*

Washington.—The weather was too dry in most localities to favor the rapid growth of vegetation, and, although a warm April on the average, there were such cool and frosty nights as to retard the progress of crops considerably. Some of the frosts, notably those of the 9th and 10th, were killing to early vegetables and certain fruits, such as cherries and prunes. Winter and spring wheat, barley, and hops made satisfactory progress, while grass, oats, gardens, and field potatoes grew slowly.—*G. N. Salisbury.*

West Virginia.—Light snowfall and freezing temperatures were general over the State from the 16th to 19th, but at other times the weather was fine and pleasant. At the close of the month wheat, rye, and grass were in very fair condition, and plowing for corn had progressed rapidly. Oat sowing was about completed, and potatoes were coming up. Some cherries, plums, and pears were killed by the freeze, but the prospects for peaches and apples, especially the latter, were better than expected.—*E. C. Vose.*

Wisconsin.—The month was colder and drier than usual, with freezing temperature generally over the State on the 6th and 7th. No serious damage occurred, as vegetation was not sufficiently advanced to be liable to injury. Winter wheat, rye, and grasses made good progress. Seeding of oats, barley, spring wheat, and spring rye was generally completed by the middle of the month, except in extreme northern counties. Preparations for corn and potatoes were well advanced by the end of the month.—*W. M. Wilson.*

Wyoming.—Over most of the State the month was too cool for the growth of crops and ranges, and in some portions of the southern counties the soil was too wet to work, and seeding was delayed. The heavy rains and snows caused some loss of lambs, calves, and shorn sheep, but were of great benefit to meadows and ranges. By the close of the month early sown grain was up and looking green, while in some sections seeding had not been completed.—*W. S. Palmer.*

SPECIAL ARTICLES.

STUDIES ON THE DIURNAL PERIODS IN THE LOWER STRATA OF THE ATMOSPHERE.

III.—THE DIURNAL PERIODS OF THE VAPOR TENSION, THE ELECTRIC POTENTIAL, AND COEFFICIENT OF DISSIPATION.

By Prof. FRANK H. BIGELOW.

THE DIURNAL VARIATION OF THE VAPOR TENSION.

In the MONTHLY WEATHER REVIEW for December, 1902, I made some remarks upon the phenomena involved in the changes of the semidiurnal periods of the barometric pressure, the atmospheric electric potential-fall, and the vapor tension, as they occur at the surface of the earth, into the simple diurnal periods which are observed in the strata above the ground. The present series of papers properly supplements that paper, but in this connection attention is fixed upon the annual variations in these two related periodicities for the purpose of determining the exact physical processes operating to produce the transformations recorded in those periods. Especially it is proposed to lead up to an explanation of the diurnal periods in the earth's magnetic field, which seem to be simply a meteorological effect of the radiation of the sun in the lower strata of the atmosphere, through the intermediate development of currents of electric ions in connection with the prevailing distribution of the temperature.

The hourly values of the vapor tension at the surface were not available at the Blue Hill Valley Station, and I decided not to take Boston, preferring a more inland station which should be freer from seacoast influences. In consequence of the convenience of the published record at Parc St. Maur, Paris, the mean diurnal variations of vapor tension at that place for the five years, 1897–1901, were computed, the results being given in Table 3. These variations at each hour relative to the daily mean are transferred to the curves of figs. 38–49, being the lower curve of each month. In order to obtain the hourly values of the vapor tension in the free air for the levels 195, 450, and 1000 meters at Blue Hill, I proceeded as follows: The temperatures computed at these elevations in Fahrenheit degrees were read from figs. 14–25, and they may be recovered from Table 2, by reversing the sign of ΔT as there recorded. These temperatures were converted into degrees centigrade. With this as an argument the vapor tension E was taken from Table 43 in the Smithsonian Meteorological Tables, edition of 1896, for saturation. Then, with the observed relative humidity at these levels for each hour, the corresponding vapor tension, $e = E \times R. H.$, was computed, and the results are given in Tables 4, 5, and 6. These variations of the vapor tension above the surface are also transferred to figs. 38–49, the mean monthly values appearing on the zero line, and the ordinate divisions being 0.40 mm. The values of the relative humidity in the free air at Blue Hill were extracted from the same report, and for each month, at the levels 195, 400, 1000 meters, all the available data were collected. Certain interpolations were made from observations at other heights, when practicable, in order to obtain more material for the discussion. The means were taken at each hour, and plotted on diagrams, and average lines were drawn through the points, from which approximate values were found. Then these values of the relative humidity for the hours 12 a. m., 4 a. m., 8 a. m., 12 p. m., 4 p. m., 8 p. m., were placed on a second system of sheets with the months as one argument, and mean lines were drawn. From these curves, which smoothed out minor irregularities, the second approximate hourly values at six points were found, and transferred to the first system of curves, which were reconstructed by the aid of them. This method of double cross-plotting involving two approximations, as before stated, is capable of dealing successfully with very rough data. An examination of the set of curves in the figs. 38–49 "Diurnal variation of the vapor tension, Δe, in the four levels 50 meters, Parc St. Maur, Paris, 195 meters, Blue Hill summit, 400 and 1000 meters in the free air over Blue Hill," leads to the following remarks on the behaviour of this element in the lower atmosphere.

(1) The mean vapor tension for the day decreases from a maximum at all levels in July and August to a minimum in the same levels in February, and from a maximum at the surface in each month to a series of lower values with the increase in elevation. This course is parallel with the seasonal change in the temperature, as may be seen by comparing the series of curves in figs. 14–25. The vapor content of the atmosphere is strictly a function of the temperature and the sources of evaporation of aqueous vapor, but for any given locality it is a function of the temperature alone when general averages are considered.

(2) For the diurnal period at the surface the year divides into two portions: first, November to February, when the diurnal variation has a single maximum, about 3 p. m., and a single minimum, about 6 a. m.; second, March to October, when the semidiurnal period is developed with maxima about 8 a. m., 8 p. m., and minima at 4 a. m. and 3 p. m., approximately. In March the maxima are located more closely together, also in October, than in the other months, showing that there is in this connection a transition between the single diurnal and the semidiurnal periodic systems. By comparing these curves with the series of figs. 2–13, "Temperature-falls in the lower strata," it is seen that the fully developed maxima of the vapor tension occur exactly in the midst of the hours of the most rapid temperature changes, 8 a. m., 8 p. m. When the lower atmosphere is heating most rapidly from the surface upward, convection currents form, which rise in the forenoon, carrying the products of fresh evaporation with them as an increase in the vapor tension. The surfaces covered

with dew and moisture deposited during the night are in a favorable condition for rapid evaporation. The first heat of radiation on the ground acts primarily on the vegetation and fills the air with vapor as fast as the process of evaporation can proceed. The midday minimum occurs at the time of greatest effective temperature, but it is a minimum for the vapor tension because the supply of moisture for evaporation is not sufficient to keep the same degree of relative humidity at the higher temperature then prevailing. The vapor contents that rise in the first wave are carried aloft to about 2000 meters, or the height of the diurnal temperature effect, and there is not sufficient aqueous vapor at the surface to fill the air undergoing this rapid temperature change up to an equal relative humidity. The second maximum at the surface is due to a reverse process of cooling, which begins at the ground and occurs most rapidly at 8 p. m., as is seen from figs. 2–13. The convection currents at that hour are directed earthward and bring the aqueous vapor back to strata which are lowering their temperature, and, therefore, develop a higher relative humidity. This cooling action extends upward slowly, with a considerable time lag, until it gradually dies out within a few hundred meters of the ground. The single maximum of the upper strata seems to be the continuance of the forenoon maximum in the lower strata, and, except for June, July, and August, the afternoon second maximum does not develop higher than 400 meters. The entire system groups itself about the curves of the temperature-fall in a very harmonious manner. The vapor rises along the ascending slope of the temperature variation and falls again on the descending slope. This is seen clearly in the summer months, where the time of the sun's radiation covers the hours from 5 a. m. to 7 p. m. In the winter these hours are much contracted, and, the temperature being relatively low, the vapor tension has much less chance to produce the double maximum, since the true vertical convection currents are comparatively feeble.

(3) In the winter there is a marked inversion of the vapor tension in the stratum 195 meters, the summit of Blue Hill, as referred to that at the ground 50 meters, or at higher elevations 400, 1000 meters, such that a minimum occurs during the middle of the day and a maximum at night. This appears in December, January, February, March, and April; in the other months, the rising forenoon maximum reverses it back again. Whether this is a characteristic of the free air at this level, or is a peculiarity of Blue Hill summit, it is not easy to determine. It may be noted that while the mean vapor tension decreases with the height, the amplitude increases at the given elevations. The lower temperature of the higher strata causes the vapor tension to be more sensitive to masses intruding from below. The same amount of aqueous vapor will cause a greater change in the tension at low temperatures than at high, and hence the vapor contents rising from the ground causes greater amplitudes in the variation of the hourly values in proportion to the height. Thus, in July a temperature of 65°, with range from 56° to 78°, is accompanied by a change in the vapor tension $\Delta e = 0.70$ mm. at the ground, while at 1000 meters the mean temperature of 60°, with range from 57° to 62°, is attended by a variation $\Delta e = 3.50$ mm. There are numerous other circumstances which can be deduced from these diagrams, such as the gradients at each hour in the day between the different levels; the function of the vapor tensions relative to the temperatures in the free hour; the effect of the surface in disturbing free air conditions which it would be beyond the purpose of these papers to discuss at this time.

THE DIURNAL VARIATION OF THE ELECTRIC POTENTIAL GRADIENTS.

The three series of observations of the hourly values of the atmospheric electric potential gradient, that is, the fall in volts per meter, $-\frac{dV}{dn}$, which have been examined in this connection are those at Perpignan[1], Paris[2], and Greenwich[3] for the five years, 1896–1900, inclusive. For Perpignan and Paris the curves given in fig. 50 were copied from the diagrams contained in the works referred to above; while for Greenwich the data for the clear and rainy days combined, as well as for the clear days by themselves, were extracted from the annual reports; the results appear for each month in fig. 51, the clear and rainy days are printed in dotted and the clear days alone in black lines. No attention has been paid to the absolute values in volts, as it is proposed simply to discuss the causes of the maxima and the minima, rather than the amplitudes of the curves. The figs. 50, 51 show that a maximum occurs during the forenoon hours, 7 to 11 a. m., and a second maximum is found in the evening hours from 6 to 11 p. m. The Perpignan and the Paris curves suggest that the morning maximum occurs earlier by about two hours in summer than in winter, while the evening maximum is more steadily centered at 7 to 8 p. m. The Greenwich curves, on the other hand, indicate that there are really two maxima in the forenoon, and two maxima in the evening, though there is a tendency to suppress the first morning maximum at 8 a. m. in the winter, which gives this maximum the appearance of entering earlier in summer than in winter as on the French curves. The evening double maximum seems to show that the 10–11 p. m. crest is steadier than the 7–8 p. m. crest throughout the year. We have therefore to give an account of the variable 8 a. m. and 8 p. m. crests, and the comparatively steady 11 a. m. and 11 p. m. crests.

Before proceeding with this exposition, I will further introduce some curves of the daily variation of the rate of dissipation of the electric charge, $q = \frac{a-}{a+}$, as given by Zölss[4], and by Gockel[5], in the Physikalisches Zeitschrift. They appear in fig. 52 for Kremmünster in the winter, and for Freiburg in the summer and the winter. While the observations are not sufficient in number to settle definitely the normal maxima and minima, yet they appear to indicate two crests in the forenoon, 8 a. m. and 10–11 a. m., and two in the evening, 8 p. m. and 10–11 p. m., with a fifth crest about 3 p. m., as is the case with the atmospheric electric potential.

There is yet another fact which can be brought out by comparing the annual numbers of the atmospheric electric potential at Greenwich with the well known variation of the annual prominence numbers, as given by me in the Monthly Weather Review for November, 1903. The Greenwich numbers are taken from the annual reports of that observatory, and are to be found in Table 9, "Variation of the atmospheric electric potential numbers on an arbitrary scale". For the years 1881-1888 the scale seems to be different from that of the years 1890-1901 in about the ratio of 1 to 2, and I have multiplied the first set by the factor 2 to give about the same amplitude for the entire series, because the location of the crests will not be altered. There are three columns, for "All days", "Rainy days", and "Clear days", respectively. These data are plotted in fig. 53, "Annual variation of the number of solar prominences and the atmospheric electric potential," but the potential curves are plotted in an inverse sense to that of the prominences. This implies that an increase in the solar activity, which produces the prominences, at the same time operates to reduce the normal atmospheric electric potential near the surface of the earth. The number and the location of the crests

[1] Des Variations de l'Électricité atmosphérique a Perpignan, par le Docteur Fines, 1890, Comptes Rendus.

[2] Étude de la variation diurne de l'Électricité atmosphérique, Par M. A.-B. Chauveau, 1902, Bureau Central, Paris.

[3] Greenwich Magnetical and Meteorological Observations.

[4] Phys. Zeit. 5, No. 10, p. 259.

[5] Potentialgefälle und elektrische Zerstreuung in der Atmosphäre. A. Gockel, Phys. Zeit. 4, No. 30, pp. 871–876; and 5, No. 10, pp. 257–259.

make this inference probable for these two elements. We have already shown in various places, summarized in the same paper, Monthly Weather Review, November, 1903, that the force of the deflecting magnetic vector s has a variation in its annual numbers which is in synchronism with that of the prominence curve. Hence, the magnetic field varies directly, while the electrostatic field varies inversely, to that of the solar energy, as shown by the frequency of the prominences, faculas, spots, coronas, and the intensity of the radiation generally.

I have brought together the several typical curves, such as emerge from an inspection of the charts and the figures of the preceding data, in fig. 54, Section I, "Comparison of the diurnal periods of temperature-fall, pressure, temperature, vapor tension, electric potential, and coefficient of dissipation". They are to be regarded as normal types of periodicity such as occur generally most vigorously during the summer months. The temperature-fall curve is from figs. 2-13, as for July; the semidiurnal pressure and temperature curves are from figs. 26-37, with some little change in the amplitudes; the vapor tension curves are from figs. 38-49, and are those for the 50, 195, and 400-meter levels in the midsummer; the electric potential gradient is from fig. 51, and the coefficient of dissipation is from fig. 52. It should be remembered that the relative values of the ordinates vary as follows:

An increase of the ordinate upward means—

(1) A greater temperature-fall, or lowering of temperature.
(2) An increase in the pressure.
(3) A decrease in the temperature.
(4) An increase in the vapor tension.
(5) An increase in the electric potential.
(6) An increase in the coefficient of dissipation.

From fig. 54, Section II, we learn that the double crests of the electric potential and coefficient of dissipation belong one to the temperature-falls at 8 a. m. and 8 p. m., and the other to the pressure-rises at 10-11 a. m. and 10-11 p. m., while the 3 p. m. crest seems to be associated with the reversal of these curves at the time of the two minima in the afternoon. The 8 a. m. and 8 p. m. temperature maxima occur in the midst of the most rapid temperature-rise in the forenoon, and the most rapid temperature-fall in the afternoon. The semidiurnal pressure curve lags about two hours behind the temperature effect, and it must be closely associated with the dynamic effect of rapidly rising and falling vertical convection currents. The exact process involved in this retardation is worth a special investigation. The vapor tension curve, also due to temperature action in producing vertical convection currents, lags yet farther behind the temperature cause, the retardation increasing from three hours at the surface to four or five hours at higher levels. It is pointed out that this physical convection in time between the vertical and horizontal coordinates affords a means of computing the vertical velocity of the heads of the effective waves of the several kinds. One must, however, take careful note of the circumstance that the entire system is being propagated from right to left on the diagram with a velocity proportional to the linear velocity of the earth's rotation at the latitude of the station. The night effect is overtaken by the advancing cone of the day temperature waves, and this makes the vertical retardation fall to the right in ascending from the base line of the abscissas.

From these considerations it is evident that we are dealing with a temperature effect throughout this series of phenomena, and that it is confined to the lower strata of the atmosphere, within two miles of the surface, because the diurnal variation of temperature is not efficient above that level. Hence, we must conclude that they are all consequences of the solar radiation, which, as is generally admitted, is the cause of the variation of the diurnal temperature by indirect action from the ground.

I have been thus careful to explain that we are concerned simply with the lower strata of the atmosphere, and have nothing to do with the higher strata, because in the following paper I shall be able to show that the diurnal variation of the magnetic field is also a temperature effect in the lower strata of the atmosphere. We may now make some further remarks on the physical cause of the atmospheric electricity of the earth's gaseous envelope.

THE CAUSE OF THE ELECTRICITY IN THE EARTH'S ATMOSPHERE.

A brief account of some of the relations between the ionization and electric potential of the atmosphere can be found in the 4th chapter of my report on "Eclipse Meteorology" Weather Bureau, Bulletin I, 1902; see also the report by M. A. B. Chauveau, already referred to, and several papers by H. Ebert, Elster and Geitel, P. Lenard, C. Barus, and others, containing the views which have been advanced recently to account for this elusive phenomenon. It is conceded that + ions and — ions are normal constituents of the atmosphere, and that their generation and recombination, with the attendant motions of their electric charges, form the basis of this physical process. These ions are produced in very many ways in the temporary disintegration of the dynamic structures of the molecules and atoms, by which they are temporarily detached and move about in search of new places of neutralization. The most prolific source of their formation is probably the action of the short waves of the solar radiation upon the aqueous vapor of the atmosphere, whether visibly condensed or in the invisible state. There is, also, a further source of the ions in the action of the electromagnetic field of the sun operating upon the electric and the magnetic fields of the earth within the gaseous materials of the atmosphere. The complexity of the physical process is very great, and I shall confine my attention more to the modes of redistribution of the ions found in the air, and moving as currents of electricity, than to their original formation. Electric potential gradients are due to a separation of the positive and the negative charges, and ultimately the source of this energy will go back to some transformation of gravitational force. At present, the inquiry culminates in the necessity of accounting for the negative charge of the earth, which is doubtless a very difficult problem. I shall make the following suggestions regarding it.

THE NEGATIVE CHARGE OF THE EARTH.

Elster and Geitel's theory of the atmospheric electric potential assumes that the negative ions when produced in the atmosphere move to the earth, which is a conducting body, more rapidly than the positive ions, and that their accumulation upon it produces the observed charge. This surface charge, it is inferred from Linss's experiments, now verified, dissipates at the rate of discharging itself, on the average, in 100 minutes. But the researches of Simpson (Phil. Mag. 6, 589, 1903) Ebert and Ewers (Phys. Zeits. 5, No. 5, p. 135-140) throw doubt upon this view, because they have not been able to show that a conductor in ionized air receives any charge by the absorption of either kind of the ions surrounding it. Ebert, on the other hand, seeks to supply the surface charge of the earth by referring the source to radio-active constituents within the earth, which, discharging through the porous ground by the capillary action of the narrow channels, deposits the negative charges on the sides, while the positive charges are ejected. It is not clear that this process is applicable to the great oceanic areas of the earth, though these show about the same electrical gradients as the land areas, nor would this process appear to allow the negative ion contents to accumulate sufficiently in the strata of the air at some distance above the ground, to produce the high tension observed in lightning discharges and in nondisruptive strains.

There are, however, several other processes which probably contribute to the separation of the positive and negative ions, by which the former tend to accumulate in the atmosphere and the latter at the surface of the earth.

(1) The different masses of the + ions and the — ions, the + ions being much larger than the — ions, may have a differential relation to the mechanical light pressure due to electromagnetic radiation, and it is possible that the negative charges are driven before it, within the earth's atmosphere itself, more abundantly than the positive charges. If the incoming solar radiation produces + ions and — ions excessively upon impact with the top of the aqueous vapor arch, which is near the surface of the earth in the polar zones and high above the ground in the Tropics, then the — ions may be driven to the earth by the mechanical pressure of the light, while the + ions tend to remain in the higher strata. Although this is not quite parallel to the case of the formation of cathode streams in rarefied gases or the comet tails in free space, there may be some differential action of this kind that tends to separate these two kinds of ions, carrying the negative ions to the earth.

(2) Since fresh ions are produced in some way by the radiation in the existing electrostatic field, V, surrounding the earth, therefore the velocity of the motion of the nucleus carrying the charge, e, where the radius of the nucleus is R and the viscosity of the air is μ, is determined by C. Barus from the formula,

$$v = \frac{Ve}{4\pi\mu R}. \quad \text{(Science, January 2, 1903.)}$$

For $R = 10^{-6}$, $\mu = 0.0002$, $e = 200 \times 7 \times 10^{-10}$ $E. S. U.$, $v = 37$ cm/sec = 0.8 mile per hour, for the unit electrostatic field = 0.003 mile per hour for a field of 1 volt/cm. Hence, by changing the sign of e, the ion charge in the formula, those of one sign would be driven in one direction and those of the other sign in the opposite direction. This is evidently one true cause of the observed separation.

(3) Similarly, the + ions and the — ions, being generated in the free air by radiation in the midst of the magnetic field surrounding the earth, should be driven in opposite directions along the lines of force to the polar regions. As the electrostatic field tends to separate a swarm of + ions and — ions in radial directions, the + ions to higher strata and the — ions to earth, so the magnetic field tends to send + ions to one polar region and the — ions to the opposite polar region. In fact, these electric and magnetic lines of force are the natural highways of travel for the ion content of the air, and, in a word, it is my opinion that the ions are generally moving about from one place to another while they are free from the bonds of atomic and molecular combination. Of course the temperature, vapor content, and pressure may accelerate or impede these movements, as has already been pointed out by Elster and Geitel, Ebert, Gockel, and others, and so introduce the meteorological conditions which have been observed. The ions in this way become sensitive registers of the physical variation in the atmosphere, and have much interest to the meteorologist.

(4) There is yet one more cause for the earth's electric surface charge which may be the most important of all, and that exists inside the earth in the atomic circulation within its mass. W. Sutherland[6] has indicated that the static electric charge of the earth, and its magnetic field may be due to a slight displacement of the positive and the negative body charges, through a distance comparable to the diameter of a molecule, 10^{-8} cm., whereby the negative charge of the earth, as a whole, is that distance farther from the center than the positive charge. There seems to be much difficulty in understanding how this takes place physically in the earth, which should apparently be electrically conducting under high temperature and pressure, but it may be possible to escape from this criticism by resorting to the following modified conception of a dynamic rather than a static character.

It seems to be probable that atoms of matter are constituted of negative ions circulating rapidly, in connection with a larger, more inert positive charge, either inside or outside of it. The velocity of rotation of the — ions is greater than the + ions and this would imply that there is a tendency for some of the negative ions to pursue paths of larger radii than the positive ions, and also at greater angular velocity. Thus, they ought, in one way or another, to recede farther from the center of the earth than the positive ions, but in so far as their natural orbital motions are impeded they will tend to accumulate and become static charges nearer the surface of the earth. If these circulating ions, the negative ions moving more vigorously, have a tendency to become polarized as to their orbit, that is to circulate in planes perpendicular to the axis of the rotation of the earth, through the effect of the earth's deflecting force due to its own angular velocity, then, there should be integrated a resultant true magnetic field directed from north to south through the interior of the earth. It is quite likely that Southerland's view can be modified from the electrostatic basis proposed by him to this electrodynamic basis, with resulting static negative residual charge at the earth's surface, and magnetic field within the earth, sustaining that observed outside of its surface. Should this be the case, it must be inferred that similar processes go on in the sun and the stars, and that all large rotating celestial bodies are polarized magnetic spheres, with electrostatic charged surfaces. The variation of the distribution of these charges from time to time, and from region to region, constitute the source of the periodic and aperiodic disturbances with which we are becoming familiar in several different classes of observations. To whatever extent these processes are in operation within the earth, and in its atmosphere, as here outlined, and thus cause the observed general distribution of the positive electric charge in the higher strata, with the negative charge at the surface of the earth, we may properly consider the variation of the electric gradients in the atmosphere as a phenomenon resulting therefrom, in consequence of changes in the temperature conditions in the earth and in the atmosphere.

THE PERIODIC VARIATIONS OF THE ELECTRIC POTENTIAL GRADIENT IN THE EARTH'S ATMOSPHERE.

I have called attention to the fact that the electric potential gradient varies from year to year inversely to the solar prominence numbers, and, in consequence, inversely to the strength of the solar radiation, insolation, and terrestrial temperatures. An increase of the temperature of the lower atmosphere decreases the potential tension between the masses of the positive and of the negative ions. Similarly the potential gradient is greater in the polar regions of the earth where the air is cold, than at the equator where it is warm. At any given station the gradient is greater in winter than in summer. Generally, cooling the air is favorable to producing an increase of the electrical gradient. Likewise, it will be seen by referring to figs. 26–37, 50, 52, 53, 54 that the diurnal maxima of the electric potential occur at the times of the true minima of the temperature waves, 8 a. m., 8. p. m., or as modified by the correlative pressure maximum waves occurring two hours later, 10 a. m., 10 p. m. We may, therefore, conclude that one uniform physical process is concerned throughout this series of electrical gradient transformations, namely, *the air is cooled in some way whenever there is an increase of the electrical gradient.*

(5) It seems to me but a step to arrive at an equally general and valid theory of the variation of the electric potential. We need only admit that the positive ions have a stronger affinity for a gas at low temperature than for the same gas at a higher temperature. If the + ions seek regions of low temperature and the — ions move to the regions of high temperature, we have yet another cause, in addition to the four already men-

[6] A possible cause of the earth's magnetism, Terr. Mag. June, 1900. June, 1903. December, 1904. W. Sutherland.

tioned for the separation of the positive and the negative ions into two masses. Hence, in the diurnal waves of temperature the positive ions flow downward from their normal level to a lower level as the minimum of the temperature wave in the lower strata passes over the place. This implies that at the 8 a. m. and 8 p. m., local hours, a stream of + ions is directed downward, so that the positive ions as a mass approach more nearly the surface of the earth where the negative ions are already accumulated. Hence, the potential gradient of electricity will be increased in proportion to this approach. It seems that the negative stratum may be considered as quite steady in elevation, while the positive stratum rises and falls in a wave, synchronously with the passage of the temperature wave. Referring to Section III, fig. 54, the temperature curve of Section I has been plotted once more in the reverse position, to show the approach of this cold stratum to the earth. From this exposition of the facts, I assume that a current of + ions descends at 8 a. m. and 8 p. m. with the temperature wave, and that the same ions ascend at 3 a. m. and 3 p. m., while the — ions remain all the while at about the same level. This, evidently, causes the observed increase and decrease of the electric potential as observed at the surface during the 24 hours of the day. I see in the movement of the + ions from one elevation to another, while the — ions remain on or near the charged surface of the earth, the true cause of the diurnal variations of the atmospheric electric potential.

TABLE 3.—*Diurnal variation of the vapor tension at Parc St. Maur, Paris.*

Hours.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12 a.	— .10	0.0	+ .08	+ .23	+ .17	+ .18	+ .14	+ .16	— .02	— .19	— .17	— .02
1	— .08	— 0.5	+ .01	+ .16	+ .03	— .01	+ .08	+ .16	— .09	— .18	— .16	— .07
2	......	......	......	......	......	......	......	......	......	......	......	......
3	......	......	..	......	......	......	......	......	......	......	......	......
4	— .14	— .09	— .08	+ .03	— .16	— .23	— .18	— .08	— .45	— .42	— .18	— .18
5	— .18	— .13	— .15	— .02	— .19	— .26	— .23	— .15	— .55	— .49	— .34	— .22
6	— .17	— .18	— .18	— .07	.00	— .07	— .01	.00	— .56	— .56	— .37	— .20
7	— .21	— .21	— .11	+ .22	+ .22	+ .12	+ .21	+ .27	— .25	— .53	— .37	— .21
8	— .17	— .17	— .01	+ .30	+ .25	+ .26	+ .34	+ .43	+ .14	— .24	— .29	— .22
9	— .12	— .07	+ .09	+ .24	+ .18	+ .24	+ .38	+ .44	+ .38	+ .12	— .10	— .13
10	— .01	+ .01	+ .12	+ .09	+ .04	+ .10	+ .32	+ .27	+ .42	+ .28	+ .07	— .01
11	+ .05	+ .06	+ .09	— .12	— .10	— .10	+ .09	+ .02	+ .19	+ .33	+ .22	+ .08
12 p	+ .10	+ .06	+ .03	— .20	— .15	— .30	— .18	— .24	+ .04	+ .22	+ .24	+ .09
1	+ .13	+ .06	— .04	— .26	— .30	— .29	— .28	— .24	— .14	+ .25	+ .28	+ .09
2	+ .13	+ .06	— .11	— .35	— .26	— .32	— .33	— .57	— .22	+ .24	+ .24	+ .15
3	+ .18	+ .05	— .13	— .37	— .36	— .35	— .43	— .63	— .33	+ .25	+ .27	+ .20
4	+ .19	+ .08	— .14	— .41	— .39	— .27	— .43	— .64	— .15	+ .27	+ .34	+ .22
5	+ .21	+ .12	— .10	— .40	— .35	— .08	— .34	— .48	+ .11	+ .29	+ .29	+ .15
6	+ .18	+ .09	+ .01	— .22	— .22	— .10	— .26	— .14	+ .32	+ .40	+ .17	+ .14
7	+ .12	+ .13	+ .09	+ .01	+ .12	+ .24	+ .09	+ .18	+ .38	+ .29	+ .10	+ .13
8	+ .07	+ .10	+ .13	+ .16	+ .24	+ .39	+ .31	+ .24	+ .33	+ .19	+ .07	+ .08
9	+ .03	+ .10	+ .12	+ .24	+ .29	+ .39	+ .25	+ .27	+ .27	+ .11	+ .02	+ .06
10	— .05	+ .04	+ .09	+ .25	+ .47	+ .32	+ .21	+ .24	+ .18	+ .01	— .05	.00
11	— .08	+ .01	+ .08	+ .21	+ .20	+ .24	+ .17	+ .22	+ .11	— .08	— .07	— .02
12	— .10	.00	+ .08	+ .23	+ .17	+ .18	+ .14	+ .16	— .02	— .19	— .17	— .02
Means...	5.33	5.21	5.15	6.07	7.59	10.10	11.44	11.20	9.99	7.99	6.29	5.43

TABLE 4.—*Diurnal variation of the vapor tension at Blue Hill, 195-meter level.*

Hours.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12 a	+ .85	+ .71	+ .75	+1.14	+ .92	+1.12	+ .75	+ .95	+ .40	+ .69	+ .50	+ .45
1	+ .72	+ .62	+ ·67	+ .94	+ .87	+ .80	+ .56	+ .40	+ .39	+ .39	+ .48	+ .45
2	+ .49	+ .52	+ .47	+ .75	+ .78	+ .13	+ .55	— .10	+ .11	+ .22	+ .42	+ .43
3	+ .33	+ .36	+ .33	+ .47	+ .65	— .04	+ .24	— .30	— .17	+ .05	+ .34	+ .34
4	+ .14	+ .26	+ .21	+ .21	+ .19	— .11	+ .10	— .43	— .44	— .06	+ .11	+ .27
5	+ .04	+ .06	+ .03	+ .15	— .08	— .16	— .01	— .49	— .71	— .24	— .03	+ .12
6	— .08	— .10	— .10	— .06	— .33	— .47	— .21	— .74	— .94	— .43	— .16	.00
7	— .25	— .21	— .30	— .11	— .57	— .50	— .41	— .46	—1.07	— .60	— .36	— .10
8	— .31	— .35	— .37	— .29	— .46	— .24	— .57	— .56	— .93	— .59	— .45	— .19
9	— .43	— .47	— .56	— .23	— .46	— .31	— .69	— .41	— .49	— .52	— .42	— .23
10	— .46	— .51	— .57	— .32	— .37	+ .05	— .34	— .02	+ .03	— .40	— .27	— .28
11	— .52	— .49	— .59	— .29	— .39	— .14	— .11	+ .28	+ .26	— .13	— .12	— .22
12 p	— .51	— .54	— .56	— .38	— .33	+ .22	+ .41	+ .59	+ .46	— .10	— .04	— .28
1	— .50	— .48	— .56	— .46	— .37	— .29	+ .37	+ .53	+ .55	+ .03	— .01	— .33
2	— .49	— .43	— .46	— .65	— .43	— .01	+ .28	+ .68	— .55	+ .03	— .07	— .30
3	— .49	— .34	— .41	— .67	— .35	— .08	— .11	+ .22	+ .33	+ .09	— .17	— .30
4	— .47	— .27	— .20	— .60	— .37	— .25	— .20	+ .19	+ .11	— .01	— .34	— .29
5	— .38	— .22	— .14	— .58	— .33	— .46	— .45	— .16	+ .06	— .02	— .24	— .25
6	— .23	— .19	— .09	— .66	— .42	— .24	— .66	— .17	+ .17	— .04	— .28	— .20
7	— .12	— .06	— .01	— .48	— .37	— .41	— .63	— .48	+ .11	— .06	— .28	— .17
8	+ .04	— .03	+ .09	— .39	— .05	— .45	— .55	— .26	— .08	— .03	— .21	— .12
9	+ .34	+ .22	+ .32	+ .06	— .02	— .10	+ .05	— .10	+ .17	+ .10	— .10	+ .06
10	+ .54	+ .47	+ .60	+ .46	+ .41	+ .33	+ .12	+ .05	+ .26	+ .34	+ .04	+ .18
11	+ .79	+ .58	+ .65	+ .87	+ .79	+ .52	+ .79	+ .60	+ .34	+ .46	+ .16	+ .37
12	+ .85	+ .71	+ .75	+1.14	+ .92	+1.12	+ .75	+ .95	+ .40	+ .69	+ .50	+ .45
Means...	2.06	2.13	2.63	3.78	6.39	9.49	12.37	11.76	8.69	4.76	3.29	2.16

TABLE 5.—*Diurnal variation of the vapor tension at Blue Hill, 400-meter level.*

Hours.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12 a.	+ .13	+ .06	+ .01	— .09	+ .10	— .46	— .11	— .19	+ .20	+ .22	+ .12	+ .13
1	+ .14	.00	— .02	— .15	+ .13	— .51	— .48	— .30	+ .31	+ .29	+ .18	+ .16
2	+ .13	— .06	— .03	— .21	+ .17	— .59	— .74	— .53	+ .31	+ .31	+ .23	+ .17
3	+ .09	— .10	— .06	— .25	+ .13	— .64	—1.01	— .70	+ .26	+ .31	+ .25	+ .17
4	— .01	— .14	— .08	— .31	+ .10	— .73	—1.11	— .82	+ .09	+ .34	+ .25	+ .16
5	— .12	— .17	— .11	— .31	— .12	— .73	—1.11	— .93	— .07	+ .09	+ .13	+ .07
6	— .19	— .19	— .15	— .31	— .32	— .73	—1.08	— .82	— .23	— .06	— .12	— .01
7	— .22	— .20	— .19	— .29	— .55	— .64	—1.01	— .70	— .45	— .18	— .19	— .10
8	— .22	— .22	— .21	— .22	— .64	— .46	— .74	— .53	— .49	— .29	— .23	— .15
9	— .20	— .20	— .17	— .15	— .65	— .28	— .52	— .36	— .49	— .29	— .21	— .16
10	— .15	— .15	— .10	— .03	— .48	— .05	— .30	+ .01	— .28	— .24	— .12	— .16
11	— .06	— .03	— .02	+ .10	— .15	+ .29	— .05	+ .26	— .01	— .09	— .07	— .16
12 p.	+ .06	+ .11	+ .11	+ .27	+ .10	+ .59	+ .27	+ .48	+ .43	+ .03	— .02	— .15
1	+ .13	+ .17	+ .20	+ .47	+ .35	+ .95	+ .48	+1.01	+ .48	+ .12	— .02	— .15
2	+ .15	+ .21	+ .24	+ 56	+ .51	+1.11	+ .74	+1.29	+ .54	+ .12	— .04	— .14
3	+ .09	+ .21	+ .25	+ .63	+ .58	+1.44	+ .89	+1.47	+ .54	+ .09	— .08	— .12
4	+ .13	+ .22	+ .27	+ .53	+ .51	+1.49	+1.00	+1.24	+ .41	+ .03	— .12	— .10
5	+ .08	+ .20	+ .24	+ .34	+ .35	+1.16	+1.07	+ .80	+ .22	— .09	— .12	— .07
6	+ .03	+ .14	+ .17	+ .25	+ .17	+ .64	+1.00	+ .42	— .12	— .18	— .12	— .02
7	— .02	+ .08	+ .09	— .05	+ .03	+ .09	+ .94	+ .11	— .33	— .29	— .10	+ .02
8	— .05	+ .05	+ .01	— .11	— .12	— .19	+ .74	— .19	— .49	— .29	— .02	+ .07
9	— .05	+ .01	— .04	— .15	— .12	— .37	+ .50	— .30	— .49	— .26	+ .04	+ .09
10	— .03	+ .02	— .06	— .15	— .12	— .41	+ .22	— .30	— .49	— .09	+ .13	+ .11
11	+ .04	+ 03	— .04	— .13	— .12	— .54	— .05	— .30	— .17	+ .12	+ .12	+ .14
12	+ .13	+ .06	+ .01	— .09	+ .10	— .46	— .11	— .19	+ .20	+ .22	+ .12	+ .13
Means...	1.59	1.57	1.74	3.02	5.40	7.43	10.10	9.57	8.32	4.45	3.14	1.90

TABLE 6.—*Diurnal variation of the vapor tension at Blue Hill, 1000-meter level.*

Hours.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12 a	+ .21	+ .12	+ .16	+ .06	+ .09	— .31	— .15	+ .21	+ .26	+ .34	.00	+ .22
1	+ .17	+ .11	+ .08	— .05	— .16	— .68	— .49	— .24	+ .17	+ .27	— .03	+ .20
2	+ .08	+ .07	+ .00	— .15	— .42	— .96	— .64	— .84	— .03	+ .10	— .16	+ .07
3	+ .03	+ .01	— .08	— .22	— .53	—1.22	—1.39	—1.28	— .31	— .09	— .30	— .06
4	— .09	— .04	— .09	— .26	— .67	—1.32	—1.64	—1.56	— .62	— .27	— .33	— .11
5	— .14	— .07	— .09	— .24	— .80	—1.32	—2.00	—1.60	— .87	— .42	— .44	— .17
6	— .17	— .09	— .03	— .20	— .74	—1.19	—1.84	—1.49	— .94	— .37	— .44	— .21
7	— .22	— .07	— .02	— .14	— .72	— .96	—1.55	—1.27	— .88	— .36	— .44	— .29
8	— .20	— .05	— .05	— .09	— .58	— .62	—1.29	— .90	— .78	— .36	— .29	— .26
9	— .16	— .07	— .09	— .10	— .43	— .27	— .95	— .53	— .48	— .27	— .13	— .20
10	— .15	— .07	— .10	— .06	— .09	+ .04	— .37	— .10	— .18	— .21	+ .04	— .14
11	— .15	— .08	— .15	+ .02	+ .04	+ .44	+ .06	+ .28	+ .14	— .08	+ .10	— .09
12 p	— .16	— .09	— .16	+ .07	+ .20	+ .61	+ .49	+ .63	+ .46	+ .06	+ .19	— .05
1	— .14	— .09	— .10	+ .07	+ .38	+ .94	+ .74	+1.04	+ .55	+ .22	+ .34	— .05
2	— .14	— .07	— .05	+ .06	+ .52	+1.21	+1.26	+1.22	+ .95	+ .22	+ .32	— .03
3	— .11	— .04	— .01	+ .07	+ .51	+1.28	+1.51	+1.34	+ .95	+ .18	+ .32	+ .01
4	— .09	— .01	+ .03	+ .13	+ .61	+1.37	+1.64	+1.21	+1.05	+ .12	+ .28	+ .02
5	— .01	— .02	+ .02	+ .17	+ .57	+1.24	+1.70	+1.09	+ .65	+ .03	+ .20	+ .05
6	+ .09	— .01	+ .03	+ .14	+ .51	+1.05	+1.70	+ .85	+ .56	+ .03	+ .15	+ .06
7	+ .19	+ .01	+ .01	+ .12	+ .43	+ .71	+1.64	+ .55	+ .43	.00	+ .10	+ .11
8	+ .23	+ .05	+ .06	+ .14	+ .37	+ .43	+1.29	+ .38	+ .20	— .03	+ .10	+ .17
9	+ .24	+ .06	+ .13	+ .10	+ .37	+ .08	+ .91	+ .21	+ .10	+ .06	+ .08	+ .19
10	+ .23	+ .11	+ .17	+ .13	+ .37	+ .04	+ .53	+ .02	+ .24	+ .19	+ .08	+ .21
11	+ .24	+ .14	+ .18	+ .13	+ .23	— .27	+ .09	+ .09	+ .23	+ .35	+ .05	+ .22
12	+ .21	+ .12	+ .16	+ .06	+ .09	— .31	— .15	+ .21	+ .26	+ .34	.00	+ .22
Means...	1.37	1.32	1.73	2.82	4.66	5.94	8.73	8.15	6.42	4.37	2.91	1.82

TABLE 7.—*Diurnal variation of the atmospheric electric potential, Greenwich observations, on an arbitrary scale. Clear days.*

Hours.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12 a	— 1	— 4	+ 4	+ 6	+ 4	+ 6	+ 5	+ 6	0	— 1	— 2	+ 2
1	— 7	— 7	— 1	+ 2	0	+ 3	+ 3	+ 3	— 5	— 4	— 7	— 2
2	— 9	—12	— 7	— 1	— 3	+ 2	+ 1	+ 1	—10	— 7	— 6	— 6
3	—11	—14	— 9	— 4	— 6	0	— 2	— 2	—11	— 9	— 8	—11
4	—12	—14	— 9	— 5	— 8	— 2	— 3	— 4	—11	—10	— 8	—14
5	—14	—13	— 7	— 2	— 7	— 2	— 1	— 4	—14	—12	— 8	—14
6	—14	—12	— 4	+ 2	— 2	0	+ 3	— 1	—13	—12	— 6	—12
7	— 9	— 6	0	+ 9	+ 7	+ 4	+ 4	+ 1	—10	—12	— 3	— 9
8	— 6	— 4	+ 2	+11	+10	+ 1	+ 1	+ 1	— 7	—13	— 1	— 7
9	— 2	— 1	+ 2	+ 5	+ 3	— 2	+ 1	0	— 2	— 7	0	— 3
10	+ 6	+ 8	+ 6	+ 1	+10	+ 3	+ 7	+ 6	+ 8	+ 1	+ 9	+ 2
11	+10	+ 7	+ 4	— 3	+ 4	— 2	+ 3	+ 3	+ 9	+ 5	+ 5	+ 9
12 p	+ 4	+ 1	— 2	— 9	— 6	— 5	— 3	— 2	+ 4	0	+ 3	+ 6
1	+ 4	— 2	— 5	—11	— 8	— 8	— 7	— 5	+ 1	+ 2	+ 2	+ 7
2	+ 4	— 1	— 7	—10	— 9	— 9	—10	— 8	— 1	+ 2	+ 2	+ 6
3	+ 6	+ 2	— 8	—10	— 9	— 9	— 8	— 8	— 1	+ 4	+ 3	+ 5
4	+ 7	+ 6	—10	— 9	— 5	— 9	— 6	— 8	+ 1	+ 9	+ 4	+ 5
5	+ 7	+ 8	— 3	— 6	— 1	— 6	— 5	— 7	+ 7	+14	+ 6	+ 6
6	+ 8	+10	+ 2	— 3	+ 1	— 4	— 3	— 2	+11	+14	+ 6	+ 7
7	+ 7	+12	+ 8	0	0	— 3	— 2	+ 2	+13	+11	+ 4	+ 5
8	+ 7	+10	+11	+ 5	+ 1	— 1	— 1	+ 4	+12	+ 7	+ 3	+ 4
9	+ 6	+ 7	+10	+ 7	+ 7	+ 6	+ 5	+ 8	+ 9	+ 7	+ 4	+ 9
10	+ 5	+ 7	+10	+ 9	+10	+11	+ 9	+10	+ 6	+ 8	+ 5	+ 9
11	+ 2	+ 3	+ 5	+ 5	+ 6	+10	+ 7	+ 6	+ 3	+ 4	+ 2	+ 6
12	— 5	— 3	— 2	— 1	+ 2	+ 6	+ 4	+ 2	— 4	+ 1	— 2	+ 2
Means...	76	84	73	66	60	42	44	45	49	56	49	71

In my next paper I will show that this action, at the same time, produces the diurnal variation of the magnetic field as observed at the surface of the earth.

TABLE 8.—*Diurnal variation of the atmospheric electric potential; Greenwich observations; rainy and clear days.*

Hours.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12a	0	− 2	+ 1	+ 4	+ 5	+ 7	+ 5	+ 6	− 4	− 1	0	+ 3
1	− 7	− 3	− 2	+ 3	+ 2	+ 5	+ 3	+ 3	− 3	− 5	− 3	− 3
2	− 9	− 9	− 5	− 3	− 3	0	− 1	+ 3	− 6	− 6	− 4	−10
3	−11	−10	− 8	− 5	− 7	− 1	− 4	− 1	− 9	− 8	− 7	−13
4	−14	−12	− 8	− 6	− 9	− 4	− 5	− 3	−10	−10	− 7	−14
5	−13	−12	− 6	− 7	− 8	− 3	− 2	− 3	−12	−11	− 7	−14
6	−14	−10	− 3	− 5	− 5	− 1	− 1	− 2	−12	−12	− 7	−12
7	−10	− 6	+ 2	+ 2	+ 4	+ 1	+ 2	0	− 9	− 8	− 5	− 6
8	− 8	− 4	+ 6	+ 6	+ 6	− 1	+ 2	0	− 6	− 7	− 4	− 2
9	− 5	0	+ 2	+ 1	+ 4	− 3	+ 1	− 1	− 1	− 2	− 3	+ 1
10	+ 5	+ 6	+ 6	− 2	+ 4	+ 4	+ 9	+ 6	+ 6	+ 4	+ 2	+ 6
11	+ 8	+ 9	+ 2	− 2	+ 2	− 2	+ 5	+ 3	+ 7	+ 3	+ 3	+ 6
12p	+ 4	+ 1	0	− 6	− 6	− 2	0	+ 1	+ 2	− 1	+ 2	+ 4
1	+ 6	0	0	− 5	− 8	− 6	− 6	− 7	+ 1	0	+ 1	+ 1
2	+ 5	− 1	− 3	− 2	−10	− 8	− 9	− 6	− 1	0	+ 1	+ 2
3	+ 6	+ 2	− 2	− 4	− 6	− 3	− 8	−12	− 1	+ 2	+ 3	+ 2
4	+ 8	+ 8	− 4	− 4	− 2	− 4	− 6	− 6	+ 1	+ 9	+ 3	+ 4
5	+ 5	+ 7	+ 2	− 3	+ 1	− 4	− 7	− 5	+ 5	+10	+ 3	+ 7
6	+ 8	+ 9	+ 7	+ 1	+ 1	− 2	− 1	+ 2	+ 9	+12	+ 4	+ 8
7	+10	+ 9	+ 8	+ 7	+ 6	+ 1	− 2	+ 3	+10	+ 9	+ 5	+ 7
8	+ 6	+ 7	+ 5	+ 9	+ 3	+ 3	− 2	+ 4	+ 8	+ 5	+ 4	+ 2
9	+ 4	+ 6	+ 6	+ 6	+ 9	+ 6	+ 6	+ 7	+ 6	+ 5	+ 3	+ 9
10	+ 5	+ 6	+ 5	+11	+12	+10	+10	+13	+ 6	+ 7	+ 4	+ 8
11	+ 4	+ 3	+ 2	+10	+11	+ 9	+ 9	+ 9	+ 3	+ 5	+ 2	+ 3
12	+ 1	− 3	− 1	+ 4	+ 5	+ 6	+ 6	+ 5	0	− 2	− 2	+ 2
Means	62	68	62	56	52	37	42	39	44	47	43	53

TABLE 9.—*Annual variation of the atmospheric electric potential; Greenwich observations; on an arbitrary scale.*

Years.	All days.	Rainy days.	Clear days.	Factor.	All days.	Rainy days.	Clear days.
1881	262	....	....		524	....	....
1882	210	121	287		420	242	574
1883	264	152	340		528	304	680
1884	236	117	299		472	234	598
1885	234	85	328	× 2 =	468	170	656
1886	224	127	301		448	254	602
1887	305	176	388		610	352	776
1888	285	169	370		570	338	740
1889	....	....	....	....	....	....	....
1890	....	....	....	....	629	433	725
1891	....	....	....	....	542	376	670
1892	....	....	....	....	465	332	557
1893	....	....	....	....	553	421	663
1894	....	....	....	....	514	358	661
1895	....	....	....	....	761	623	880
1896	....	....	....	....	661	516	768
1897	....	....	....	....	586	459	679
1898	....	....	....	....	483	342	553
1899	....	....	....	....	343	184	432
1900	....	....	....	....	450	338	539
1901	....	....	....	....	593	417	680

THE OBSERVATIONS WITH KITES AT THE BLUE HILL OBSERVATORY, 1897-1902.

By Prof. FRANK H. BIGELOW.

In June, 1904, the Blue Hill Observatory published its observational data on the meteorological elements in the lower strata of the atmosphere, temperature, humidity, and wind vectors at various heights up to about 4000 meters, as derived from the kite ascensions made during the years 1897-1902, and in March, 1905, a discussion of these data by Mr. H. H. Clayton was distributed. These observations are greatly needed in American meteorology, and they constitute the first comparatively complete series of results that have been placed in the hands of students in the United States. In 1898 the U. S. Weather Bureau published in Bulletin F, compiled by Mr. H. C. Frankenfield, the results of the observations made during a six months campaign at sixteen stations in the Mississippi and Ohio valleys, besides one at Washington, D. C. These ascensions were made in the warm half of the year, May to October, and in the daytime, so that the resulting gradients are larger than can be accepted for the mean of the day and the mean of the year. Since the full problem requires the determination of the gradients for each hour of the day, and for each month in the year, in order that any application may be reliable in theoretical discussions of the circulation of the atmosphere, or in solar meteorology, those observations could not be extended to such questions. A practical handling of the Blue Hill data, comprising numerous ascensions at all hours of the day and night, and in all months during five years, shows that even this amount is very meager as compared with the demands of meteorology. As a valuable contribution, however, the Blue Hill observations are welcome to students, and I am very glad to express my obligations to those who have executed this laborious investigation. A careful examination of the data leads us to believe that the ascensions were skilfully conducted, and that the results are reliable up to the degree of precision at present attainable in that class of work. My own discussion of these data, of which an account is given in the MONTHLY WEATHER REVIEW for February, 1905, "The diurnal periods of the temperature," was executed in the interval between the appearance of the first and the second parts of the work, and, hence, the results obtained by me are independent of those published in the Blue Hill discussion. Since the general conclusions are in agreement, we may be confident that the observations bear the interpretation placed upon them by Mr. Clayton and by myself, and while the scope of the treatment is different in the two cases, since I had questions of cosmical meteorology in mind, there is no important divergence in the principal results. I have sought, in my treatment of the observations, to avoid composite curves of the gradients, by discussing the data for each month of the year, as explained in my paper, intending to gain thereby a working program for the organization of the Mount Weather Observatory, and for the correlation of several outstanding problems in barometry, ionization, and magnetism of the atmosphere. As Mr. Ward has given a suitable summary of Mr. Clayton's results in Science, March 17, 1905, and as the report of my conclusions may be found in the series of papers in the MONTHLY WEATHER REVIEW, February to July, 1905, "Studies on the diurnal periods of the lower strata of the atmosphere," it is not necessary to repeat those remarks in this connection. It will be proper, however, to make some suggestions arising from these studies, with a view to their application in work of a similar kind upon the meteorological elements in the lower strata of the atmosphere.

(1) *Mixed systems of data.*—Great trouble is certain to result in meteorological studies from the indiscriminate employment of the metric system, the English system, or the English and metric systems combined. The European data are usually in the metric system, the English and the American data are generally in the English systems, but the Blue Hill data are given in a mixed system—height in meters, wind velocity in meters per second, and temperature in degrees Fahrenheit. To translate these three classes of data across from one system to the other, as is required in every cosmical investigation, adds such labor to the work as to make the difficulty of executing the research much greater than it ought to be. Obviously, we can not approve of introducing mixed systems of data into meteorology, while so much effort is being made to reduce the two primitive systems to a single system.

(2) *Gradients referred to a summit station.*—It is evident that the summits of hills or mountains offer great advantages in mechanical kite flights, over valley or low-level stations, because the prevailing winds are fresher, and this facilitates the starting of an ascension. Also, the elevated sites are somewhat freer of the irregular gusts which prevail in the surface stratum within a few hundred feet of the ground. Yet, with this advantage, there is introduced, on the other hand, an increase in the scientific complexity in handling the observed data, because the gradients in the lowest strata are very unequal, as between day and night, or from one month to another, so that the temperature-falls, or the temperature gradients referred to the summit, can not be taken as equivalent to those in the free air over a great plain, without very careful corrections. All general gradients must be corrected for the hour of the day and to a low-level surface, or the plain country, before they can be introduced into the equations of cyclones